How to Argue Concerning Theoretic Principles: Lessons from the History of Cosmology

By: Claus Beisbart

Theoretical principles play an important role in science. With theoretical principles, I mean principles that put forward a substantive scientific claim (not just methodological rules) and that are foundational for some specific branch of science in that they guide theory-building or modeling in that branch.

Now, on a simple empiricist construal of science –on a Popperian model of science, say –there is not much to be argued concerning such principles. Theories that contain the principles are to be tested empirically, and for that, certain consequences may be derived from the principle deductively –but any further argument concerning the principles amounts to mere speculation. In particular, the introduction of a principle is no more than a bit of guesswork. This view is sometimes justified using the distinction between the context of justification and the context of discovery. But the view contradicts the appearance (to say the least) that there has been argument accompanying the introduction of theoretical principles in the history of science quite apart from empirical tests. The aim of this paper is to identify patterns of arguments of that type. For realizing this aim, certainly an integrated approach is required that combines philosophy and history of science. I turn to the history of relativistic cosmology for a case study and consider the way the Cosmological Principle was introduced. This case is particularly well-suited for my purposes, because in the early days of relativistic cosmology, the data were very sparse and subject to large errors.

Very roughly the Cosmological Principle states that the Universe is spatially homogeneous and isotropic everywhere. Obviously, this principle puts forward a substantive claim regarding the Universe. Also, it is foundational for cosmology in that many observations and calibrations rely on the Cosmological Principle. In its present form, the Cosmological Principle somehow dates back to Einstein's 1917 paper on cosmology. The name "Cosmological Principle" was coined by Milne (1935) who referred back to a later work by Einstein in which Einstein states that all places in the Universe are on par (Einstein 1931).

My paper traces the history of the origination of the Cosmological Principle in the work of Einstein, Milne, Robertson, Walker and others. I highlight the following points.

First, the principle had some kind of predecessor. For instance, G. Bruno, in this "De l'Infinito Universo et Mondi" (1584) suggested on theological grounds that space that is infinite according to Bruno is more or less homogeneously filled with matter. A similar suggestion was made by Kant (1755).

Second, the predecessor of the Cosmological Principle figured centrally in a purely theoretical problem for a Newtonian cosmology, and Einstein's General Theory of Relativity provided some means to get rid of this problem. The problem is this: If space as pictured by Newtonian physics (i.e. infinite Euclidian space) is homogeneously filled with matter, then the force on a test-particle is not well-defined any more. It is sometimes suggested that Newtonian cosmology is inconsistent on that count (see Malament 1995, Norton 1999 and 2002 for discussion), but I think this mis-describes the situation. Rather, I would say, the problem is that what was supposed to be an intended application of the theory (the matter distribution of the Universe on large scales) did not turn out to provide a well-posed boundary value problem. This indicated that something was wrong with the assumptions of Newtonian Cosmology. Einstein's General Theory of Relativity fundamentally changed the situation in this respect, because it altered the law of gravitation and because it allowed for spaces different from infinite Euclidean space.

But third, there was also some argument on how to square the Cosmological Principle with the General Theory of Relativity. For in the way formulated thus far, the Cosmological Principle presupposes a distinction between space and time –a distinction that is observer-dependent according to both theories of relativity. It was therefore argued that the Cosmological Principle was at odds with relativity. The Principle needed a careful reformulation. That reformulation amounts to a translation of the principle from one theoretical framework (or paradigm, if you like) to another one –from Newtonian physics to general relativistic physics, in our case. Work by Milne and Walker was pivotal for that endeavor. That the reformulation worked in some way is remarkable, if Newtonian and relativistic physics are semantically incommensurable, as has been suggested by Kuhn (1962), for instance.

Fourth, remarkably, the Cosmological Principle was in a way applied in relativistic cosmology much before a rigorous formulation was obtained. As a consequence, there is some indeterminacy of when exactly the Cosmological Principle was first considered in general relativistic physics. As another suggestion, it seems it was crucial for the establishment for the Cosmological Principle that it picked a class of solutions that can be specified analytically and that it was fruitful in this respect.

Fifth, there was some argument concerning the justification of the Cosmological Principle: Is there any ground to assume the Cosmological Principle in the first place? In this respect, it was argued by some that the Cosmological Principle somehow naturally flows from a principle that underlies the General Theory of Relativity –viz. the Principle of General Covariance. Such claims have been taken up by philosophy (K. Hübner).

All in all, the case study suggests at least the following patterns of arguments that may accompany the introduction of a principle: 1. One can argue against a principle by showing that, given some theory, it leads to a problem that is not well-posed in the theory of differential equations. 2. Careful argument is needed to formulate a principle in a new theoretical framework. For this, a principle from a predecessor theory may be translated, or otherwise vague ideas may be precisified. 3. One can argue in favor of a principle by establishing its fruitfulness for further investigation. 4. One may argue for a principle by showing that it naturally flows from principles that underlie the derivation of the theory in which the principle is applied (arguably, this kind of argument isn't very successful in cosmology). Notably, most of these arguments are holistic in that they involve other principles or a theoretical background.